Analysis of the ultraviolet radiation profile based on measurements from the UTVM-UNAM solarimetric station and its effects on health

Análisis del perfil de radiación ultravioleta basado en mediciones de la estación solarimétrica UTVM-UNAM y sus efectos sobre la salud

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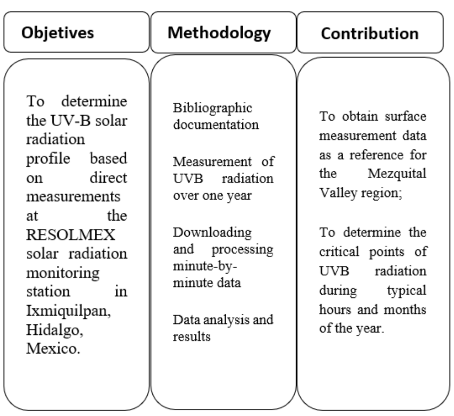
Abstract

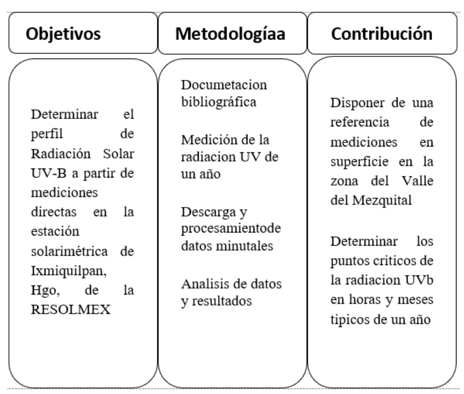
The need to understand solar energy drives the analysis of solarimetric and meteorological data, as mentioned by (Frederick & Lubin, 1988), who contributed significantly to understanding the effects of UV-B on the Earth's surface and its relationship to the ozone column, as also stated by asegura (Modronich, 1993) in his atmospheric studies. Direct, in-situ measurement of UV-B radiation is essential to establish models and methodologies for its estimation, laying the foundation for more detailed analysis. This research focuses on the dissemination and universal access to science and addresses a study centered on the analysis of the solar ultraviolet type B radiation profile in Ixmiquilpan, Hidalgo, Mexico, based on minute-by-minute measurements at the Ixmiquilpan solarimetric station. The fundamental purpose of this research is to interpret its temporal and spectral profile, obtaining a characteristic curve for each month, as well as annual averages and maximum values in MED/h and UVB index.



Radiation, UV-B, Solar

Resumen

La necesidad de comprender la energía solar, impulsa el análisis de datos solarimétricos y meteorológicos, como lo menciona (Frederick & Lubin, 1988), quienes contribuyeron significativamente a la comprensión de los efectos de la UV-B en la superficie terrestre y su relación en la columna de ozono, así como también lo asegura (Modronich, 1993) con su estudio de la atmosfera. La medición directa en sitio radiación UV-B es fundamental para establecer modelos y metodologías para su estimación, sentando bases para su análisis más detallado. La investigación se enfoca a la Difusión y acceso universal a la ciencia y aborda un estudio centrado en el análisis del perfil de la radiación ultravioleta solar tipo B en Ixmiquilpan, Hidalgo México, a partir mediciones realizadas cada minuto en la estación solarimétrica Ixmiquilpan. El propósito fundamental de esta investigación es interpretar el perfil temporal y espectral de la misma, obteniendo una curva característica de cada mes, los promedios y máximos anuales en MED/hr e índice UVB.



Radiación, UV-B, Solar

Area: Promotion of frontier research and basic science in all fields of knowledge

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Introduction

This work presents an analysis of UV-B radiation, aligned with the dissemination and universal access to science. UV-B radiation is a portion of the solar electromagnetic spectrum with wavelengths generally between 290 and 320 nanometers, although some sources define it in the range of 280 to 315 nm (Modronich, 1993). This research seeks to identify patterns, variations, and, crucially, critical points where radiation presents atypical profiles or values of interest.

The results actively contribute to the scientific community by providing a UV-B radiation profile from on-site measurements, promoting new research lines in solar energy, its applications, and implications. In addition, this work contributes to the efforts of other members of the Mexican Solarimetric Network (RESOLMEX), aiming to develop local action plans that may also contribute to global research efforts. Recommendations are proposed in response to adverse UV-B radiation values. The intensity of UV-B radiation reaching the Earth's surface depends on the time of day, altitude, atmospheric conditions such as ozone and clouds, and the amount of aerosols (OMS, 2003).

The magnitude of this radiation affects material durability and has biological importance due to its ability to interact with living organisms, potentially causing cellular damage (uvb.nrel.colostate.edu, 2025), However, it is also essential for vitamin D production in human skin (FDA, 2025). Extreme values prompt preventive measures to avoid health risks.

1.- Ultraviolet Radiation and the Electromagnetic Spectrum

Ultraviolet radiation has shorter wavelengths than visible light and ranges from 10 nm to 400 nm (Lazara & Perez, 2022); Lázara & Pérez Below 200 nm, this radiation is toxic to living beings. Ultraviolet radiation is classified into three categories: UVA (315–400 nm), UVB (280–315 nm), and UVC (100–280 nm) (Lazara & Perez, 2022).

The Sun emits radiant energy in all directions, including large explosions that cause solar wind affecting our planet.

The Earth's atmosphere filters and sustains life, allowing UV radiation near 300 nm to pass through (Modronich, 1993), Radiation from 10 to 120 nm is highly energetic but absorbed by the atmosphere, which is beneficial because it increases thermal energy and atmospheric ionization. This study found that filtered radiation levels are lower than expected, revealing higher values—an important finding for deeper analysis.

Figure 1 shows a simulation of ultraviolet radiation observed from outer space

Box 1

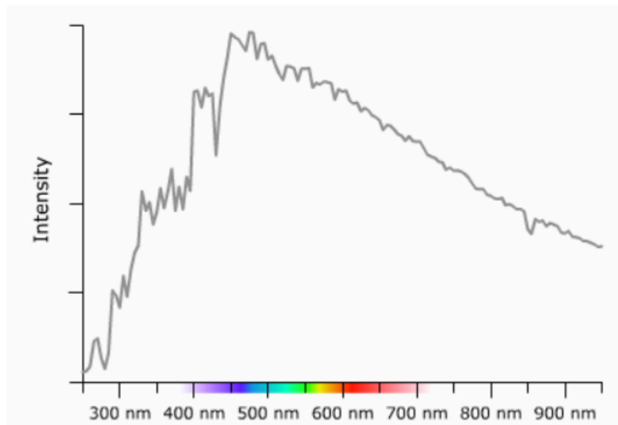

Figure 1
Simulation of the solar spectrum observed from outer space
Source: Nebraska Astronomy Applet Project (NAAP), 2020

2.-Understanding Ultraviolet B (UVB) Radiation

UVB radiation is characterized by its wavelength range, which is between 290 and 320 nanometers, according to the most commonly accepted definition (Modronich, 1993). It is important to note a slight variation in this range, as some sources place it between 280 and 315 nm (Modronich, 1993). Compared to Ultraviolet A (UVA) radiation, which has longer wavelengths, UVB possesses shorter wavelengths and, therefore, higher energy levels. This higher energy of UVB photons is a key factor in its biological effects (Modronich, 1993). A distinctive feature of UVB radiation is its interaction with the Earth's atmosphere. Unlike UVA, which is practically not absorbed by the ozone layer, and Ultraviolet C (UVC), which is completely filtered by the atmosphere, UVB is partially absorbed by the stratospheric ozone layer (Modronich, 1993).

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Article

This partial absorption means that a fraction of the solar UVB radiation manages to reach the Earth's surface. According to the WHO, the majority of ultraviolet radiation remains in the atmosphere (90%); additionally, this radiation increases by 4% every 300 meters in altitude (OMS, 2003), In this investigation, it is observed that this does not align with what is described by the OMS, as it increases more than what is considered for the monitoring point's altitude. According to the observed data, this means the UV-B radiation levels are higher and, consequently, more harmful to the health of living beings.

3.- The Effects of UVB Radiation on the Skin

The biological effects of UVB radiation are significant. It is well known that UVB is the primary cause of sunburn (NEDA - Northeast Dermatology Associates, 2025) and mainly affects the outer layers of the skin, known as the epidermis (Diffey, 1991).

However, UVB radiation also plays a crucial role in the skin's synthesis of vitamin D (Ultraviolet (UV) radiation, 2025) an essential process for bone and muscle health (FDA, 2025). It also has the ability to directly damage the DNA in skin cells, which in the long term can increase the risk of developing skin cancer, including melanoma (Diffey, 1991). It is crucial to know that the permissible level of sun exposure depends on the skin pigmentation type, from light to dark (see Table 1). As can be observed, it has less impact on people with dark skin.

Box 2

Table 1
Skin type classification

Fototipo de piel	Color de piel	Sensibilidad a la radiación	Descripción
I	Blanca (deficiente en melanina)	Muy sensible	Siempre se quema con facilidad tras la exposición al Sol, raramente se broncea.
II	Blanca (deficiente en melanina)	Muy Sensible	Habitualmente se quema tras la exposición al Sol, algunas veces se broncea.
III	Blanca (con melanina suficiente)	Sensible	Algunas veces se quema tras la exposición al Sol, habitualmente se broncea de manera gradual y uniforme, (café claro).
IV	Café Clara (con melanina suficiente)	Moderadamente sensible	Raramente se quema tras la exposición al Sol, siempre se broncea bien. (café moderado).
V	Café (con protección melanica)	Mínimamente sensible	Rara vez se quema. Se broncea intensamente (café oscuro).
VI	Café oscuro o negro (con protección melanica)	Insensible o mínimamente sensible	Nunca se quema. Se broncea intensamente (café oscuro o negro).

Source: Global Solar UV Index, Practical Guide. OMS, OMM, PNUMA y el ICNIRP. 2003

Knowing skin pigmentation and the UV index, there are studies that show the maximum recommended time for direct exposure to solar radiation in order to avoid adverse health effects (see Figure 2).

Box 3

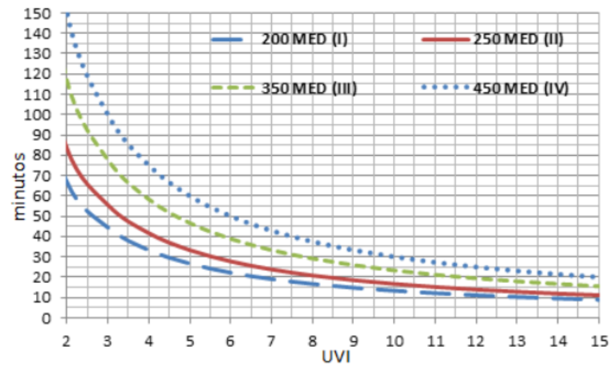

Figure 2
Exposure time in minutes associated with UVI according to skin type
Source: Technical Note N° 002-2016 SENAMHI, pag. 59

As shown in Figure 2, the effect on the skin will depend on the exposure time, the magnitude of UVB radiation, and skin pigmentation. It visualizes the time in minutes necessary to accumulate a 1 MED dose as a function of the UVI and skin type, serving as a guide to take precautions and not exceed the permissible time. Ignoring this can cause erythema, or sensitive skin reddening, for different UVI levels and for each skin type (OMS, 2003), This research shows that the maximum exposure a human being with type IV skin can have in the region of analysis, with a UVI index of 12, is no more than 25 minutes of direct exposure.

Exposure to solar ultraviolet UVB radiation beyond the permissible limit will cause harmful effects on the organism, such as immediate injuries ranging from minor skin reddening to actual burns, or delayed injuries like photoaging, photosensitivity, actinic keratosis, skin cancer, and cataracts. (Diffey, 1991) and (OMS, 2003).

4. Radiaton Intensity UV-B

Figure 3. Shows the factors that influence UV-B radiation levels. The intensity of solar radiation varies due to diverse factors, depending on the situation; according to the time of day and the season of year. Outside of tropical zones, the highest UV radiation intensities occur when the sun reaches its maximum altitude, around solar noon during the summer months (Diffey, 1991) and (OMS, 2003).

The factors to consider regarding intensity are:

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Latitude: The closer to the equator, the more intense the UV radiation (OMS, 2003).

Cloud cover: UV radiation intensity is highest when there are no clouds, but it can be high even with cloud cover. Scattering can produce the same effect as reflection from different surfaces, increasing the total UV radiation intensity (OMS, 2003).

Altitude: At higher altitudes, the atmosphere is thinner and absorbs a smaller proportion of UV radiation. With every 1000-meter increase in altitude, UV radiation intensity increases by 10% to 12% (OMS, 2003).

Ozone: Ozone absorbs part of the UV radiation that would otherwise reach the Earth's surface. Ozone concentration varies throughout the year and even throughout the day (OMS, 2003).

Ground reflection: Different types of surfaces reflect or scatter UV radiation to varying degrees; for example, fresh snow can reflect up to 80% of UV radiation; dry beach sand, around 15%; and sea foam, around 25% (OMS, 2003).

Box 4

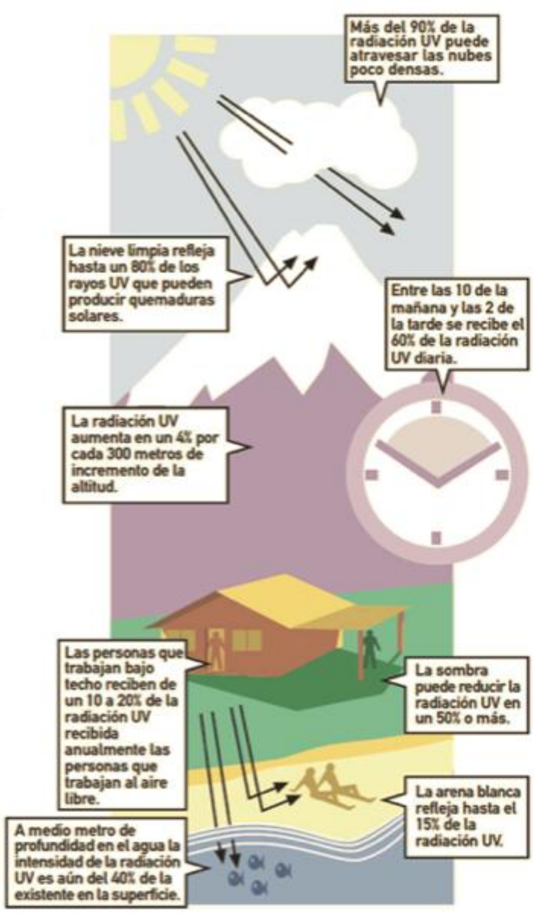

Figure 3

Some factors modify the levels radiations UV-B

Source: OMS, OMM, PNUMA y el ICNIRP

5. Influence of Solar Angle and Atmospheric Path at 2000 masl

At an altitude of 2000 masl, the effect of the sun's daily cycle on UVB intensity is accentuated due to the lower atmospheric density. During the central hours of the day, when the solar angle is high and the path of light through the atmosphere is shorter, the UVB intensity will be even greater at 2000 masl than at sea level under the same solar angle. This is because the lesser amount of atmosphere present offers fewer opportunities for the absorption and scattering of radiation (OMS, 2003) and (Blumthaler & Ambach, 1990).

On the other hand, during the early morning and late afternoon hours, although the general UVB intensity is lower, the reduction compared to the midday peak could be proportionally similar to that observed at sea level. However, the absolute UVB intensity values will still be higher at 2000 masl compared to sea level for the same solar angle (OMS, 2003) and (Blumthaler & Ambach, 1990).

It is important to consider that the ratio between UVA and UVB radiation intensity varies throughout the day. Generally, this ratio is higher in the morning and afternoon, and lower at midday (LearnSkin, 2025). While UVA intensity tends to remain relatively constant during daylight hours, UVB intensity experiences more significant fluctuations based on the solar angle (LearnSkin, 2025). At 2000 masl, this daily variation in the UVA/UVB ratio could have different implications for skin damage and vitamin D synthesis compared to sea level, although the information provided does not specifically detail this aspect, as the altitude in this case is not 2000 masl but is very close.

6. Atmospheric Scattering and Absorption of UVB Radiation

The Earth's atmosphere contains various components that interact with solar radiation, including UVB, through scattering and absorption processes. Ozone (O3) is one of the primary absorbers of UVB radiation in the stratosphere (uvb.nrel.colostate.edu, 2025). Furthermore, air molecules, mainly nitrogen and oxygen, are responsible for the Rayleigh scattering of UV radiation (NOAA Antarctic UV Monitoring Network, 2025).

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Aerosols and dust particles present in the atmosphere also contribute to the scattering and absorption of radiation (Solar and ultraviolet radiation - NCBI, 2025)

At an altitude of 2000 masl, the concentration of these atmospheric components is lower compared to lower altitudes. This lower concentration results in less absorption and scattering of UVB radiation. Therefore, a greater amount of incident UVB manages to reach the surface at this altitud (OMS, 2003) and (Blumthaler & Ambach, 1990).

The solar radiation that reaches the Earth's surface is composed of a direct part, which comes directly from the sun, and a diffuse part, which is the radiation that has been scattered by the atmosphere. (Solar and ultraviolet radiation - NCBI, 2025). It is estimated that a significant portion of UVB, around 70% at a wavelength of 300 nm, corresponds to the diffuse component (Solar and ultraviolet radiation - NCBI, 2025).

At high altitudes, with a thinner atmosphere, the proportion between direct and diffuse UVB radiation could differ from that observed at sea level, which could influence how UVB interacts with surfaces and living organisms. Nonetheless, the consulted documents do not offer specific data on this proportion at 2000 masl, so this is considered another finding.

7. Modification of UVB Patterns by Cloud Cover and Other Atmospheric Conditions

The presence of clouds can significantly alter the amount of UVB radiation that reaches the Earth's surface (UVA vs. UVB Rays: What's the Difference - Healthline, 2025). In general, clouds tend to reduce UVB through absorption and reflection processes (Stratosphere: UV Index: Effects of Clouds - Climate Prediction Center, 2025). However, the magnitude of this effect depends on the type, thickness, and density of the clouds. Thin or scattered clouds may have a minimal effect, and even dense clouds do not completely block UVB (UVA vs. UVB Rays: What's the Difference - Healthline, 2025). Studies indicate that up to 80% of UV rays can pass through clouds (NEDA - Northeast Dermatology Associates, 2025)

It is crucial to highlight the "partly cloudy sky effect," where scattered clouds can even increase UVB radiation due to reflection and scattering (Can Harmful UV Rays Get Through the Clouds, 2025)] Increases of up to 25% or even higher have been reported under these conditions (Stratosphere: UV Index: Effects of Clouds - Climate Prediction Center, 2025). Furthermore, clouds are generally more effective at blocking visible light than UV radiation.

Other atmospheric conditions, such as weather, dust, and air pollution, can scatter UVB radiation, which could reduce the amount that reaches the surface (American Scientist , 2025,) However, the specific impact of these factors at 2000 masl could be different due to the lower overall concentrations compared to lower altitudes.

8. The Daily Cycle of the Sun and UVB Radiation Intensity

The intensity of UVB radiation reaching the Earth's surface is strongly conditioned by the sun's angle relative to the horizon, known as the solar elevation angle (LearnSkin, 2025). Throughout the day, this angle undergoes significant variations. The sun is at its lowest point on the horizon during sunrise and sunset, reaching its maximum elevation around solar noon (Sunwise Toolkit and Samples, 2025).

This variation in the solar angle has a direct impact on the distance that sunlight must travel through the Earth's atmosphere. When the sun is at a high angle, near the zenith, the light passes through a smaller portion of the atmosphere (UVA vs. UVB Rays: What's the Difference - Healthline, 2025). Conversely, in the early morning and late afternoon hours, the sun is at lower angles, which means the sunlight must travel a longer path through the atmosphere (UVA vs. UVB Rays: What's the Difference - Healthline, 2025). As a result of this difference in the atmospheric path, UVB radiation intensity is typically highest around solar noon, the time when the sun reaches its maximum height in the sky (LearnSkin, 2025). Various sources agree that the period of maximum UVB intensity usually occurs between 10 a.m. and 4 p.m. (UVA vs. UVB Rays: What's the Difference - Healthline, 2025), with a more pronounced peak between 11:30 a.m. and 1:30 p.m. (UVA and UVB in sunlight, Optimal Utilization of UV rays in Sunlight for phototherapy, 2025).

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A practical rule for estimating UVB intensity is to observe the length of an object's or person's shadow. The shadow rule states that the intensity of UVB rays is lower when the shadow is longer than the object's height, which occurs during the morning and afternoon. In contrast, the intensity is highest when the shadow is shorter than the height, a situation that occurs around midday. (LearnSkin, 2025).

9. Impact of Altitude (2000 masl) on UVB Radiation

Altitude is a determining factor in the intensity of UVB radiation that reaches the Earth's surface. As altitude increases, the atmosphere becomes less dense and thinner (Cancer Council NSW, 2025). This lower atmospheric density implies a smaller quantity of molecules capable of absorbing and scattering UV radiation, including UVB (Cancer Council NSW, 2025).

As a direct consequence, the intensity of UVB radiation increases with altitude (UVA vs. UVB Rays: What's the Difference - Healthline, 2025). Various studies have attempted to quantify this increase. It is estimated that for every 1000-meter increase in altitude, UVB radiation levels can increase by 10% to 12% (Cancer Council NSW, 2025), or approximately 12% (Hong Kong Observatory, 2025). Other research suggests an increase of around 7% per kilometer of altitude (The Relationship between Ultraviolet Radiation Exposure and Vitamin D Status - PMC, 2025), while a specific study found an increase of 19% per 1000 meter (Applied and Environmental Microbiology - ASM Journals, 2025).

Considering this data, at an altitude of 2000 masl, a significant increase in UVB radiation intensity would be expected compared to sea level. Based on the 7% to 12% increase range per 1000 meters, UVB intensity at 2000 masl ranges from 14% to 24% higher than at sea level. The 19% per 1000 meters figure suggests an even greater increase of 38%. It is evident that people at this altitude are exposed to considerably higher levels of UVB radiation. (Applied and Environmental Microbiology - ASM Journals, 2025).

Box 5

Table 2

Percentage increase in UV-B intensity per 1000 meters above sea level according to various sources

Source	Percentage Increase per 1000 meters
(Cancer Council NSW, 2025)	10-12%
(Hong Kong Observatory, 2025)	approximately 12%
(The Relationship between Ultraviolet Radiation Exposure and Vitamin D Status - PMC, 2025)	Around 7%
(Applied and Environmental Microbiology - ASM Journals, 2025) 0	19%

Source: Compiled from the sources mentioned

8.- Equivalence of Ultraviolet Radiation to Exposure Category

It is imperative to know the factor level of the radiation that the Earth's crust receives and that impacts living beings. Below, data obtained from NASA (see Table 3) focused on the Mezquital Valley Region are shown.

Box 6

Table 3

Ultraviolet Radiation en mW/m^2

LAT	LON	YEAR	ALLSKY_SFC_UVA
19.5	-102.5	2023	280
19.5	-101.5	2023	260
19.5	-100.5	2023	270
19.5	-99.5	2023	240
19.5	-98.5	2023	260
20.5	-102.5	2023	270
20.5	-101.5	2023	250

Source: NASA Data Base

According to (apogee, 2024) the relationship between the UV index and UV radiation can be approximated by dividing it by 5.7. Figure 4 shows the W/m2 vs. UV index relationship

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Box 7

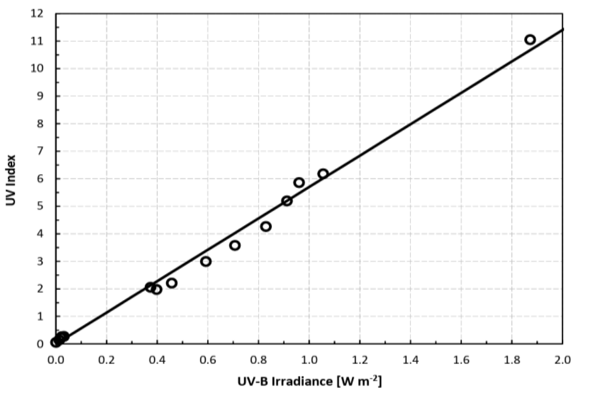

Figure 4
UV index conversion UV chart
Source: Apogee 2024

According to the NASA database, the lowest value recorded in 2023 is 0.05 Wm-2 and the maximum was 0.53 Wm-2. This data indicates that the UV index in the region of analysis ranges between 0 and 21.5, and according to the WHO, the exposure is moderate to high.

UVB Radiation Levels in Ixmiquilpan and its Measurement

As is known by the scientific community, UV radiation levels are not the same everywhere on planet Earth. As specified by (Cortez, y otros, 2011) factors such as: solar elevation, altitude, longitude, latitude, and cloud cover, among others, limit its intensity. It should be noted that the instruments used in this research are located in Ixmiquilpan, Hidalgo; Mexico, at the geographic coordinates: 20.4951° North, -99.1804° West, with an altitude of 1,700 masl. In Figure 5, the Universidad Tecnológica del Valle del Mezquital can be seen.

Box 8

Figure 5
Universidad Tecnológica del Valle del Mezquital
Source: googlemaps, 2025

To know the levels, on-site measurements are required using appropriate equipment, as in this case, a Solar Light Model 501 Biometer.

To know the levels, on-site measurements are required using appropriate equipment, as in this case, a Solar Light Model 501 Biometer.

The measurements are carried out in units of MED/hour, and the UV index, which has a scale from 1 to 15, is commonly used. The system has the capability to display, via the digital monitoring console, the UV radiation intensity in MED/Hour units. Since Ultraviolet Index (UVI) units are normally used in various places, a conversion factor of 2.332 [(MED/Hour * 2.332 = 1 UVI] (02-UVI-Calculations-2-7, 2006), is used, which is the same one employed in this study.

Data acquisition and preprocessing help obtain the solar radiation profile in Ixmiquilpan. The solar radiation profile analysis allows for the identification of the UV-B Radiation level through a critical point analysis and the periods in which they occur.

Table 4 presents the MED/hour equivalent for the 15 UV Index values.

Box 9

Table 4
Equivalentes en MED/hora los 15 valores del IUV

Indice UV	med/Hr
0	0
1	0.43
2	0.86
3	1.29
4	1.72
5	2.14
6	2.57
7	3
8	3.43
9	3.86
10	4.29
11	4.72
12	5.15
13	5.57
14	6
15	6.43

Source: using a conversion factor of 2.332

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Recommendations

Given the higher intensity of UVB radiation at 1700 masl, it is crucial to adopt protective measures, even on cloudy days. It is important to note that the potential [for exposure] increases when reflective surfaces are present, such as snow, whitish soil like that of the Mezquital Valley, or water, which can be more common in high-altitude environments.

Daily UV index forecasts, which are often available, should be consulted and can be useful for planning outdoor activities.

Considering that the soil type in the Mezquital Valley area is limestone (whitish) or predominantly "tepetate" [a hard, light-colored soil], this implies it has a high reflectance of UVB radiation, increasing the intensity of exposure for people.

The most important recommendations to reduce risks are:

– Reduce exposure during the central hours of the day.
– Seek out areas where there is shade.
– Use protective clothing. (Even very thin fabric helps drastically reduce UVB intensity on the skin.)
– Use a wide-brimmed hat to protect the eyes, face, and neck. We should resume the good habits of our parents and grandparents, where wearing a hat was common, and reduce the use of baseball caps, as they cover less and reduce protection from solar radiation.
– Protect the eyes with wrap-around sunglasses or those with side panels.
– Use a broad-spectrum sunscreen with a sun protection factor (SPF) of 15+, applying it generously and as often as needed.
– Avoid tanning beds.

It is particularly important to protect babies and young children.

It would be very helpful for local media to issue alerts to the community when UVB Index values are very high, so that preventive actions can be taken.

Methodology

Given that the research is exploratory in nature, with its specific objectives, the method used for this field study is broken down as follows.

A Solar Light Model 501 Biometer is used, with a spectral range of 280-320nm and a measurement range of 0-10 MED/Hr, for permanent outdoor use. The equipment is a radiometer for solar radiation measurement systems used in meteorological stations and observatories in various parts of the world, with reproducibility for each unit (Solar Light Co. Inc., 2006), It is a high-precision instrument with instantaneous results and non-volatile memory.

This measurement is transferred via fiber optics to a data storage system on a computer using a CR3000 data acquisition system.

The information was downloaded in monthly periods for one year, where, under optimal system operation conditions, one data point per minute is continuously available.

The measurement units for UVB radiation are given in MED/hr in the database, which contains an average of 43,200 data points per month.

The information was analyzed in units of Minimum Erythemal Dose per Hour (MED/Hr). Sixty data points per hour were grouped and averaged for each hour, and then sorted by 24-hour days.

Each hour was grouped by month to calculate the average for hours 1 through 24 from the days contained in each month, in order to obtain a 24-hour monthly average profile in MED/hour units (See Table 6).

The conversion factor was applied to obtain the Ultraviolet Index (UVI), which is the most standardized value, in order to understand its effects in various areas, such as public health.

Through this analysis, the results are graphed to establish a monthly average profile and, finally, the annual profile.

The equivalent for each day per monthly period was obtained, to subsequently calculate a mean daily average for the month, which is the most important final result presented in this work.

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Subsequently, the critical hours and months of maximum radiation are identified to provide a crucial basis for public health decision-making and citizen awareness in the Valle del Mezquital.

Results

After processing a database in the range of 500,000 samples per year to analyze UVB radiation behavior, it was possible to obtain the results shown in Figure 6 and Figure 7.

It is important to mention that the graphs of the on-site measurements will allow for comparison in future stages with other indirect information sources, such as via software or other platforms like NASA's, which has information obtained from satellites.

Box 10

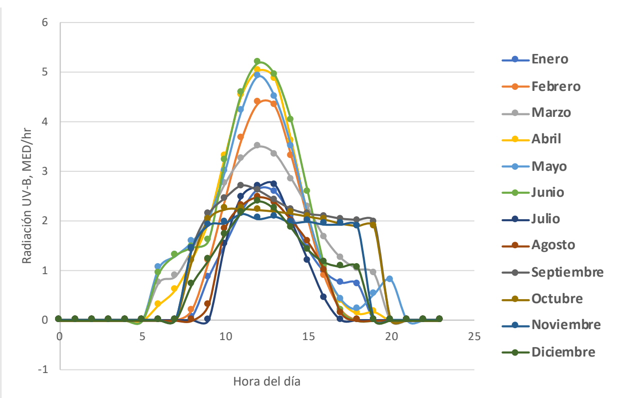

Figure 6
Average daily radiation profile UV-B, MED/Hr
Source: Own Elaboration

Box 11

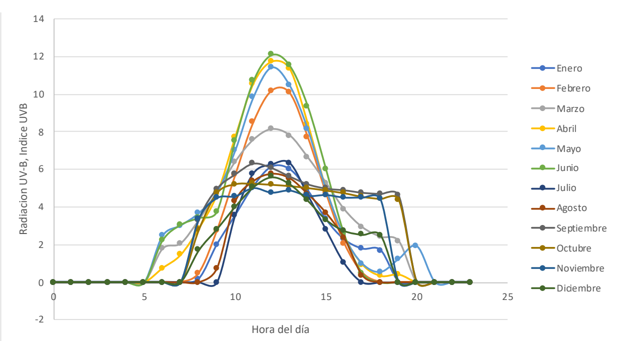

Figure 7
Average daily UV-B radiation profile, UVB INDEX
Source: Own Elaboration

In Figure 7, it can be seen that there are UVB radiation peaks of up to 12 UVI in the month of June, which corresponds with the warmest periods in the Mezquital Valley region. Likewise, it can be observed that the months with the highest intensity were from February to June; in the remaining months, it decreases. This is justified by the planet's tilt relative to the sun, as the radiation arrives at a steeper angle relative to the horizon in the northern latitude, and by the onset of the rainy seasons and the arrival of winter in Mexico.

Therefore, the period from February to June is when the population should be urged to be careful during periods of direct sun exposure. Critical Hours: The period of greatest UV-B intensity is typically found between 10:00 a.m. and 2:00 p.m.

Box 12

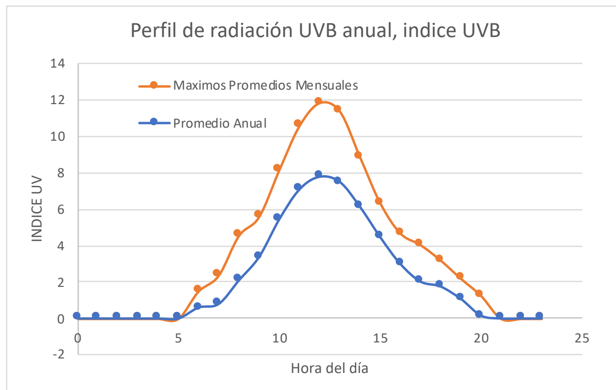

Figure 8
Annual average daily profile of UV-B radiation, average and maximums, UV INDEX
Source: Own Elaboration

Analyzing the final graph of the average and maximums, it can be observed that there are periods of the year with UVB radiation indices of 12, making it possible that, on particular days, these values are exceeded, which represents a greater risk during prolonged sun exposure. Considering Table 5, in the region in question, we are experiencing UVB intensities considered extremely high according to the OMS.

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Box 13

Table 5

UVB Intensity, Color Scale, and International Exposure Category

CATEGORÍA DE EXPOSICIÓN	INTERVALO DE VALORES DEL IUV
BAJA	<2
MODERADA	3 A 5
ALTA	6 A 7
MUY ALTA	8 A 10
EXTREMADAMENTE ALTA	11 +

Source: IndiceUV Solar Mundial: Guía práctica de la OMS Organización Meteorológica Mundial (PNUMA y Comisión Internacional de Proteccion contra Radiación no ionizante, 2003

Conclusions

The behavior of UVB radiation at an altitude of 1700 masl during the day is characterized by a daily cycle with an intensity peak around solar noon. Due to the lower atmospheric density at this altitude, UVB levels are significantly higher compared to sea level during all hours of the day. The solar angle influences UVB intensity, with shorter atmospheric paths resulting in higher levels. The presence of clouds can modify this pattern, generally reducing the intensity.

Other atmospheric factors can also have an impact. Understanding these patterns is fundamental for taking appropriate precautions and protecting the health of the population at high altitudes, especially during the hours of 10 a.m. to 2 p.m. and the most intense months detected (February to June), where UVB indices are on the order of 12, which is considered extremely high.

In sum, the study provides the first reference of in-situ measurements for this area, establishing that exposure during peak hours and months of highest intensity demands the implementation of urgent preventive measures. It is recommended that local health authorities and media outlets disseminate early warnings about the UVI and promote the adoption of essential protective measures, such as the use of sunscreen, hats, sunglasses, and the reduction of exposure during the highest-risk hours.

It should be noted that these profiles can change due to atypical years; therefore, subsequent years must continue to be characterized to see how this variable evolves over time, and so that in the future the data can be compared with other RESOLMEX stations to quantify its variation due to altitude differences.

Annexes

The 60-minute-per-hour data was averaged to provide one data point per hour, daily, which is equivalent to 720 average data points per month. This was grouped into daily hours to obtain Table 6, which means there are 12 equivalent tables

Box 14

Table 6

Promedios horarios en MED/hora

	Dias									
HORA	1	2	3	4	5	6	7	8	....	30
0	0.80893	0.80872	0.80318	0.76142	0.79182	0.77322	1.08292	1.11933	....	-0.00425
1	0.81933	0.81452	0.81042	0.76827	0.80393	0.78998	1.07223	1.13488	....	-0.00433
2	0.82112	0.81512	0.80968	0.76797	0.80938	0.79427	1.11293	0.09462	....	-0.00418
3	0.83578	0.82705	0.83355	0.78402	0.81452	0.78685	0.07440	0.04528	....	-0.00323
4	0.85090	0.84065	0.83705	0.79285	0.81805	0.80092	0.23395	0.06427	....	-0.00472
5	0.86263	0.84983	0.84635	0.81125	0.83468	0.79922	-0.13273	0.12640	....	-0.00403
6	0.88173	0.86730	0.86548	0.83940	0.84712	0.81953	-0.10040	0.27395	....	0.02133
7	1.00455	1.04508	1.09905	1.64623	0.69147	0.86672	0.87760	0.53597	....	0.26757
8	1.84108	2.06615	2.03642	1.96612	0.80248	1.68078	1.41680	1.55297	....	1.01485
9	2.24687	2.20767	2.25388	2.06828	2.08808	1.76175	1.83388	1.74938	....	2.32625
10	2.20018	2.12630	3.98213	3.92277	3.67967	1.82122	3.18508	2.45782	....	3.94463
11	2.17787	2.10905	5.32670	5.31717	4.94948	1.96853	4.43337	4.49458	....	5.24030
12	2.04608	2.07723	6.08578	5.78190	5.54367	4.64890	5.11420	5.23518	....	5.84265
13	2.05728	2.17175	5.48185	5.51860	5.27247	4.82027	5.10850	5.12245	....	5.53930
14	2.07108	2.13088	3.97613	4.45230	4.13595	3.90778	3.89037	1.68842	....	4.21790
15	1.98072	1.93103	2.45373	2.82017	2.56305	2.49282	2.29805	1.74682	....	2.53335
16	1.87345	1.98313	1.25465	1.25747	1.12660	1.05910	1.17377	1.03223	....	0.98430
17	1.67858	1.75760	0.30727	0.32530	0.83605	0.30930	0.30510	0.28228	....	0.30750
18	0.79808	0.87580	0.02903	0.21467	0.68537	-0.06048	0.02600	0.02687	....	0.03493
19	0.76408	0.76060	0.56177	0.63278	0.66053	0.00060	0.00410	-0.00390	....	-0.00213
20	0.75695	0.77355	0.77320	0.68472	0.76585	0.35963	1.03263	-0.00463	....	-0.00297
21	0.78907	0.79885	0.76725	0.78523	0.77223	1.03790	1.13632	-0.00500	....	-0.00322
22	0.79997	0.79458	0.75770	0.79020	0.76990	1.25108	0.86955	0.06672	....	-0.00345
23	0.80037	0.79407	0.75893	0.80152	0.76918	1.00352	1.02397	0.45018	....	-0.00315

Source: based on data from the Ixmquilpan, Hgo. solarimetric station

Declarations

Conflict of interest

The authors declare no conflicts of interest. No financial interests or personal relationships exist that could have influenced the content of this article.

Author contribution

Demillón Pascual Rufino, is the Researcher and technical manager responsible for providing technical maintenance for the solarimetric station, downloading data, organizing the information downloaded over a year, and processing it month by month.

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López Mendoza, Israel; Collaborates on the documentation for the development of the theoretical framework and the study design.

Callejas Mejía, Miriam: collaborates by reviewing the graphs obtained from the UV-B radiation and analyzing the profiles.

Trejo Leal, Huber Baltazar: Collaborates in reviewing the structural writing of the scientific article.

Availability of data and materials

The data belong to the Mexican Solarimetric Network (RESOLMEX) and its members, of which we are a part as the Ixmiquilpan solarimetric station, which is in collaboration with the Universidad Tecnológica del Valle del Mezquital (UTVM) and 12 additional (HEIs [Higher Education Institutions] and Research Centers) institutions at the national level.

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Abbreviations

CEMIESOL	Centro Mexicano de Innovación en Energía Solar
IG-UNAM	Instituto de Geofisica de la Universidad Nacional Autonoma de México
masl	meters above sea level
MED	Minimal Erithemal Dose
RESOLMEX	Red Solarimetrica Mexicana
UVB	Radiación Ultravioleta B
UTVM	Universidad Tecnológica del Valle del Mezquital
UVI	Indice Ultravioleta

References

Basic

02-UVI-Calculations-2-7. (2006). *CULCyT//Septiembre–Diciembre, 2006, Año 3, No 16-17 , pag. 12, .* Obtenido de http://meteo.lcd.lu/uvi_calculator/02-UVI-Calculations-2-7.PDF

Diffey, B. L. (1991). *Solar ultraviolet radiation effects on biological systems*. *Physics in Medicine and Biology, 36(3), 299–328. 1.*

Frederick, J. E., & Lubin, D. (1988). Te bugdet of biologically active ultraviolet radiation in the hear-atmosphere system. Journal of Geographycal Researh: Atmospheres, 93(D3), 3825-3832

Lazara, A., & Perez, M. (2022). *La radiación ultravioleta y su impacto ambiental*. Editorial Solar.

Modronich, S. (1993). *La otmosfera y la radiación UV-B a nivel de suelo. MTevini (Ed), Radiación UV-B y agotamiento de Ozono: Efectos sobre los humanos, animales, plantas, microorganismos y materiales (pp. 1-39).* CRC Press.

NEDA - Northeast Dermatology Associates. (4 de abril de 2025). *What You Need to Know About UV Radiation*.

Solar and ultraviolet radiation - *NCBI*. (2025 de Abril de 2025).

uvb.nrel.colostate.edu. (4 de Abril de 2025).

Support

American Scientist . (4 de abril de 2025,). *Sunshine on a Cloudy Day*.

Applied and Environmental Microbiology - ASM Journals. (04 de abril de 2025). *Diverse Responses to UV-B Radiation and Repair Mechanisms of Bacteria Isolated from High-Altitude Aquatic Environments*.

apogee, i. (20 de junio de 2024). *ULTRAVIOLET INDEX* . Obtenido de ULTRAVIOLET-B SENSOR: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/

Can Harmful UV Rays Get Through the Clouds. (4 de abril de 2025).

Cancer Council NSW. (4 de abril de 2025). *Factors that affect UV radiation levels*.

Cortez, A., Enciso , J., Reyes, C., Arriaga, E., Romero, C., Ribes, J., . . . Hernández, M. (2011). El índice ultravioleta en el ámbito laboral: un instrumento educativo. *Medicina y Seguridad del Trabajo, 57*(225), 319-330. doi:https://dx.doi.org/10.4321/S0465-546X2011000400006

LearnSkin. (4 de abril de 2025). *UVA/UVB Rays & Sun Exposure & Change Ratio*.

OMS. (10 de junio de 2003). *Índice UV Solar Mundial*. Obtenido de Guía práctica: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/

Solar Light Co. Inc. (2006). Manual del usuario, . *UV - BIOMETER* . Philadelphia. , USA: Copyright 2006.

Stratosphere: UV Index: Effects of Clouds - Climate Prediction Center. (4 de Abril de 2025).

Sunwise Toolkit and Samples. (4 de abril de 2025).

The Relationship between Ultraviolet Radiation Exposure and Vitamin D Status - PMC. (04 de abril de 2025).

Ultraviolet (UV) radiation. (4 de abril de 2025).

UVA and UVB in sunlight, Optimal Utilization of UV rays in Sunlight for phototherapy. (4 de abril de 2025).

Differences

Blumthaler, M., & Ambach, W. (1990). *Indication of increasing solar ultraviolet-B radiation flux in alpine regions. Science, 248(4952), 206–208*.

FDA. (04 de abril de 2025). *Ultraviolet (UV) Radiation*.

Hong Kong Observatory. (4 de abril de 2025). *Ultraviolet radiation at high altitude*.

NOAA Antarctic UV Monitoring Network. (4 de abril de 2025).

UVA vs. UVB Rays: What's the Difference - Healthline. (4 de abril de 2025). Obtenido de

(uvb.nrel.colostate.edu, 2025)

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